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Review Article

A comprehensive review on morphological, genetic and phytochemical diversity, breeding and bioprospecting studies of genus *Chlorophytum* Ker Gawl. from India

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ABSTRACT

India presently comprises 23 species of *Chlorophytum* which are commercially utilized as 'White gold' or 'Divya aushadhi'. There are pressing demands on the biodiversity and bioresources of Western Ghats and *Chlorophytum* is one of the highly demanded medicinal entities, as *Chlorophytum* has export value and there is a vast demand for its roots under the trade name 'Safed Musali'. The roots of various species are collected from nature. Even all the species of *Chlorophytum* are not studied properly for taxonomy, morphology, medicinal value and antioxidant contents. The present review proposes a comprehensive impression of phytogeographical survey, morphological, genetic and phytochemical diversity, medicinal properties and uses, field studies and breeding practices of genus *Chlorophytum*. Conclusively, the anticipated article is an endeavour to provide a complete update of several studies led by members of the genus *Chlorophytum* that will possibly be utilized systematically and appropriately in different conservation strategies and sustainable development.

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1. Introduction

Natural populations of medicinal plant species are extensively utilized due to their massive demands. In this context, long-term existence, as well as semi-domesticated nature of many medicinal plants need the maintenance of adequate genetic variability within and among populations to assist new selection pressures exerted by constant environmental changes (Barrett and Kohn, 1991). The potential use of a variety of medicinal and herbal plants and the existence of a variety of valuable natural compounds belonging to a variety of natural compounds groups, and their direct impact on human life. In this relation, Mohammadhosseini et al. (2021a) reviewed phytochemical characteristics of the genus *Aloysia* Palau (Verbenaceae) which comprises several remedial properties in folk medicine by different countries and discussed their essential oil profiles, phytochemistry of the polar isolated sections, the related biological actions with the suggestion of future investigation on less-studied species and probable evaluation of toxicological impacts of the genus. Similarly, Mohammadhosseini et al. (2021b) reviewed the chemical profiles of the essential oils (EOs), non-volatile compounds, ethnobotany, and biological activities of different species of the genus *Haplophyllum* from family Rutaceae. 40 different species of genus *Ruta* L. of citrus family Rutaceae are distributed in Mediterranean region. Nahar et al. (2021) critically and systematically evaluated the literature with reference to the content and biological activities of the essential oils from *Ruta* species and briefly outlooked on the potential applications of nanotechnology and chitosan-based products of it. Mouthe Kemayou et al. (2021) covered traditional uses, the phytochemical and pharmacological investigations of the genus *Ekebergia* (Meliaceae) in the review which covered 69

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isolated compounds which belong to diverse classes of metabolites. Some of which displayed numerous bioactivities.

In India, medicinal plants are acquiring much attention and are being cultivated extensively by the farmers but many of them are yet in semi-domesticated form. Numerous studies have examined the effects of cultivation on the genetic diversity of crop plant species and forest species populations in India (Bahulikar et al., 2004; Shaanker et al., 2004; Bodare et al., 2013; Harish Gupta et al., 2014).

US health regulator has rejected the entry of 11,664 Indian products, containing drugs, and ayurvedic formulations into the American market, because of problems in branding, packaging, labeling and most important reason of rejection was adulteration (Kale and Deogade, 2016). Identification of medicinal plants by the traditional system is based on morphological characteristics and traditional attributes. This traditional method can create uncertainty while collecting the plant for the making of formulations. Likewise, morphologically closely related species show different medicinal properties (Bahmania, 2014). DNA based molecular markers are well grounded because the genetic information is distinctive for each species and is free from their age, physiological, geographical and environmental aspects (Pourmohammad, 2013). Now results obtained through molecular systematic studies can show disagreement with traditional taxonomic ideas, there has been a move to re-investigate chemical data and this has formed numerous instances of DNA sequence data approving better with chemical characters than macromorphological data (Kite et al., 2000).

Chlorophytum Ker Gawl. holds an important position in Indian herbal medicine. The demand for this plant is ever increasing in Indian and International drug market and it can become an important cash crop. Roots of *Chlorophytum* species are used medicinally as a sex tonic under the name *Safed Musli*. The Indian forests are rich in Safed Musli. The foreign demand has been estimated as 300-700 tons/ annum (Bordia et al., 1995), a quantity that Indian forests cannot sustain. Moreover, the trade is virtually in the hands of some dealers who collect the Safed Musli from wild to meet their local and foreign commitments. Hence the natural populations of *Chlorophytum* species are constantly under heavy collection pressure. The species of the genus *Chlorophytum* are difficult to identify for even taxonomists. Then what is about the local collectors? Most of the time they collect the material from all available species of *Chlorophytum* found in the region. This commercial exploitation will drive them to RET status.

There are pressing demands on the biodiversity and bioresources of Western Ghats and *Chlorophytum* is one of the highly demanded medicinal entities. As *Chlorophytum* has export value and there is a vast demand for its roots. The roots of various species are collected from nature. Even all the species of *Chlorophytum* are not studied properly for taxonomy, morphology, medicinal value and antioxidants. This comprehensive review is made to understand morphological, genetic, phytochemical diversity and applied aspects of *Chlorophytum* which can be utilized systematically and appropriately in different conservation strategies and sustainable development.

2. Phytogeographical survey of *Chlorophytum* species from India

The genus *Chlorophytum* was first established by Ker Gawler Johan Bellenden (1808) and *Chlorophytum inornatum* Ker Gawl. is the type species of the genus. The first comprehensive treatment was done by Baker (1876). Distribution of genus *Chlorophytum* Ker Gawl. is in tropical and subtropical regions of the world (Willis 1973), particularly in Africa, Asia and Australia, North America, South America, Central America and Europe. The diploid species usually grow in the plains whereas the polyploid species in the temperate zones. Most of the species belonging to genus *Chlorophytum* are generally distinguished and intended for their remedial, ornamental and economic values (Tarafder, 1983; Wolverton et al., 1984). As most of the species are reported from Africa, it is considered as the possible center of origin (Patil et al., 1987). It is the major genus of sub-family Agavoideae from the family Asparagaceae with about 212 taxa (Kativu and Nordal, 1993; APG III, 2009; Govaerts et al., 2012). One of the important genera *Chlorophytum* is distributed in Old World tropics to subtropics with ca.150 species in Africa, South East Asia and Australia (POWO, 2022; Mabberley 2017). Mukherjee (1975) reported 15 species distributed in southwestern and in north eastern India. Malpure and Yadav (2009) reported 17 species, and six new species of *Chlorophytum* have been described from India in the past decade by several authors. Presently in India, the genus is comprises of about 23 species (Chandore and Yadav 2019).

Chlorophytum arundinaceum Baker is found in the natural forests of India. It is distributed sparsely over Eastern India, Bengal, Sikkim, Bihar, Assam, Orissa and Meghalaya (Chopra et al., 1956; The Wealth of India, 2000). Due to its significance and demand in the market, a great number of farmers took up its cultivation in diverse parts of the country *viz*. Andhra Pradesh, Assam, Maharashtra, Gujarat and Rajasthan (Oudhia, 2001). Moreover, its boundless gathering from natural habitat and its ruinous garnering techniques, coupled with poor seed germination and low vegetative multiplication ratio altered it into an endangered species in the Eastern Ghats, and an upmost rare medicinal herb in India (Samantaray and Maiti, 2011). It grows in sheltered spaces, along with the borders of moist deciduous forests as well as exposed hill slopes (Adsul, 2015).

Chlorophytum bharuchae Ansari, Sundararagh. & Hemadri found in the arid hilly chunks of Maharashtra and Northern Karnataka. It is rare and sparsely distributed in dry hilly parts from Nasik to Kolhapur, Aurangabad, rare in the northern area of Belgaum.

The *C. bharuchae* is morphologically very close to *Chlorophytum kolhapurense* Sardesai, S.P.Gaikwad & S.R.Yadav and forms a distinct clade which splits them from other *Chlorophytum* species occur in India. The roots of *C. bharuchae* can produce a large amount of biomass and a potential source of saponins. It can become an alternative source of the other species of *Chlorophytum* for cultivation practices (Naik, 1974, 1979; Raghavan et al., 1977; Patil and Deokule, 2010; Adsul, 2015).

Chlorophytum borivilianum Sant & Fern is native to India, cultivated and eaten as a leafy vegetable in some parts of India. It is an endangered geophyte with a wide-ranging traditional history and medicinal importance. Its population occurs naturally in arid hilly parts and moist to dry deciduous forest areas of southern Rajasthan, western Madhya Pradesh, north Gujarat, the subtropical Himalayas from Kumaon, Khasi Hills, Bengal, Assam, Konkan, Kanara, West peninsula and Chennai outspreading to Kanyakumari (Santapau and Fernandes, 1955; Purohit et al., 1994; Sriram et al., 2012). The cultivation of *C. borivilianum* has been carried out in various chunks of India *viz*. Chhattisgarh, Gujarat, Maharashtra, Rajasthan, Haryana, Karnataka, Madhya Pradesh, and Uttar Pradesh. The area under cultivation for its tuberous roots is more than 400ha (Kothari and Singh, 2004).

Hooker (1892) reported the short scaped spider plant *Chlorophytum breviscapum* Dalz. from the foothills of Himalaya. It grows in moist deciduous to the semi-evergreen forest of the Konkan region of Maharashtra, Goa, Karnataka and Kerala (Lekhak et al., 2012; Adsul, 2015).

The species of *Chlorophytum* specifically *Chlorophytum glaucoides* Blatt and *Chlorophytum glaucum* Dalz. were recognized as discrete taxa from each other by reason of tiny well defined morphological and karyotypic differences (Naik, 1977). Both the species restricted to hilly ranges of Sahyadri in western India. The ecological ranges of distribution are not strictly bordered (Naik and Nirgude, 1980). *Chlorophytum glaucoides* chiefly occurs on high altitude hills of Northern Western Ghats of Maharashtra, Karnataka and Goa with harsh climatic circumstances *viz*. high wind and hefty rainfall. The local name 'Kapar Musli' clearly define its occurrence in the pits of the steep mountain. While, *C. glaucum* occurs in Goa, Karnataka, Maharashtra and Madhya Pradesh. Common on the boundaries of plateaus and mountain steeps of Satpura ranges, Northern Western Ghats, Kalsubai-Harishchandragad ranges and Mahadev ranges (Adsul, 2015).

Chlorophytum gothanense Malpure & S. R. Yadav is the recently described species from India which grows only in the crevices of open exposed high altitude lateritic plateaus (Malpure and Yadav 2009). Presently it is reported from Maharashtra in districts Ratnagiri, Sindhudurg, Kolhapur and Sangli. While from Karnataka it is only reported from Belgaum (Belgavi) (Adsul, 2015).

Chlorophytum heynei Rottl.ex Baker is altogether different and rare species of the genus from India. It shows similarity with African ornamental species *Chlorophytum filipendulum* subsp. *amaniense* (Engl.) Nordal & A.D.Poulsen It grows in high humus containing soil and also the rocky substratum in semi-evergreen to the evergreen forest (Adsul, 2015). Earlier the taxon was considered to be endemic to Western Ghats of Tamil Nadu. Presently the species is naturally growing as an understorey in the semi-opened areas of evergreen forests and clefts of rocks from Wagamon hills of Kottayam and Rosemala of Kollam from Kerala, Southern Western Ghats (Robi et al., 2015). This study resolved the taxonomy of misidentified and recently described species *Chlorophytum clivorum*.

Mathew and George (2015) from Achankovil, in Kollham district of Kerala. The critical analysis showed the names *C. clivorum* and *C. heynei* are of the same biological unit. Hence, *C. heynei* holds nomenclatural priority (Prabhukumar et al., 2016).

Chlorophytum indicum (Willd. ex Schult. & Schult.f.) Dress which is morphologically similar to *C. glaucum* grows in the rock crevices under the shades in the dry deciduous forests of Karnataka, Andhra Pradesh and Tamil Nadu (Sheriff and Chennaveeraiah, 1975; Adsul, 2015).

Chlorophytum kolhapurense Sardesai, S. P. Gaikwad & S. R. Yadav described by Sardesai et al. (2006) was considered to be restricted to Maharashtra. However, the rigorous field survey in peninsular India resulted in the growth of species in the dry deciduous forest of Karnataka and Tamil Nadu which indicate its wide but sparse distribution (Adsul et al., 2013).

Chlorophytum malabaricum Baker occurs on high altitude hills in moist shallow soil by exposed rocks, amidst grasses (Mathew, 1983; Murthy and Yoganarasimhan, 1990). It is distributed in Gujarat, Goa, Karnataka, Tamilnadu and Kerala (Nayar et al., 2014). The species show morphological similarity with *C. glaucoides* especially in the flower characters (Adsul, 2015).

Chlorophytum nepalense (Lindl.) Baker usually grows along the forest boundaries, grassy slopes and rocky slopes along valleys. In Indian subcontinent, the species is found in the extremely temperate zones restricted to Eastern Himalayas, Assam, Sikkim Bangladesh, Bhutan, Nepal, Sichuan, Xizang, Yunnan of China; Myanmar; Thailand. Ecologically and consequently spatially, the species serves high altitude requirement. *Chlorophytum nepalense* is an unexploited and unexplored plant partaking notable rigidity and tolerance similar to the other pharmaceutically significant members of the genus (Mukherjee, 1975; Basu and Jha, 2008).

Chlorophytum nimmonii (Grah.) Dalz. is distributed in Maharashtra, Goa, Karnataka, Tamil Nadu and Kerala (Nayar et al., 2014). It grows in moist deciduous to an evergreen forest nearby the watercourses underneath the shades of trees and bushes (Adsul, 2015).

Amidst all *Chlorophytum* species occur in India, *Chlorophytum laxum* R. Br and *Chlorophytum tuberosum,* (Roxb.) Baker shows wide-ranging distribution throughout the country, adaptation to diverse climatic conditions, existence in varied ecological circumstances and also show a large degree of variation in tubers,

leaves and scape length.

Amongst the two exotic *Chlorophytum* species first one is the *Chlorophytum filipendulum* subsp. *amaniense* (Engl.) Nordal & A.D.Poulsen also called as 'fire flash plant', is an ornamental foliage plant that joined our tropical garden, erstwhile in late 2005. It is native to the rainforests of East Africa in Tanzania. The vibrant orangy-hued petioles set contrasting to the medium green leaves make it a peerless ornamental plant, be located indoors or outdoors alike (Jacqueline and John 2008). While second exotic species *viz*. *Chlorophytum comosum* (Thunb.) Jacq. is native to tropical and southern Africa but acclimatized in other areas of the world and also named 'Spider plant' or 'Airplane plant' is a flowering perennial herb (Howell et al., 1958; World Checklist of Selected Plant Families wcsp.science.kew.org/). It is easy to grow as a houseplant and the variegated forms are most common. In the Indian garden, six different cultivars are reported by Naik (1980) cultivated in many gardens.

The Indian *Chlorophytum* species are adapted to wide-ranging habitats in the various phytogeographical regions *viz*. rocky lateritic open exposed plateaus, steep slopes amongst the grasses and forest undergrowth. Majority of the *Chlorophytum* species are habitually forest dwellers and ephemerals (Malpure and Yadav, 2009; Chandore et al., 2012). Adsul (2015) revised the genus *Chlorophytum* for India and reported the characters like anther filament ratio, number of tepal nerves, pedicel articulation and somatic chromosome number which are taxonomically significant. Presently the genus comprises 23 species (Chandore and Yadav, 2019) and a majority of them are occurring in the Western Ghats.

Novelties were discovered in the Western Ghats by ensuing critical field survey, observations and analysis of *Chlorophytum* populations (Sardesai et al., 2006; Malpure and Yadav, 2009). In recent years, more species of *Chlorophytum* have been described from Western Ghats of India: *Chlorophytum belgumense* Chandore, Malpure, Adsul and Yadav described by Chandore et al. (2012) is the critically endangered species located in Khanapur and Belgaum of Karnataka. It shows similarity with *C. arundinaceum*. *Chlorophytum palghatense* K.M.P. Kumar & Adsul, described by Prabhu Kumar et al. (2014) grows in grasslands of high mountains of Palamala hills of Dhoni forest and Elival hills of Muthikulam forests of Palakkad District in Kerala. Another novelty described by Adsul et al. (2015) is *Chlorophytum sharmae* Adsul, Lekhak & S.R.Yadav from Munnar, Kerala which shows similarity with *C. glaucum* but discriminated on the basis of narrow linear leaves with serrulate hyaline margins and late flowering. Apart from the Western Ghats species were also reported from central India from Khandwa district of Madhya Pradesh which is named as *Chlorophytum diwanjii* Mujaffar, A.P.Tiwari & Chandore by Shaikh et al. (2017). The inventory of *Chlorophytum* continued with an unusual species from Northeastern India in Behali Reserve Forest, Sonitpur district, Assam *viz*. *Chlorophytum assamicum* D.Borah & A.P.Das by Borah et al. (2019) which is an element of shady moist mixed deciduous forest. The addition of *Chlorophytum* species in the Western Ghats continued again with recent addition of *Chlorophytum tillariense* S.R.Yadav & Chandore a new species again from the high altitudinal lateritic plateaus of Tillari area of Maharashtra by Chandore and Yadav (2019), which shows close empathy to *Chlorophytum gothanense* Malpure & S.R.Yadav

Documentation of the distribution and diversity of medicinal plants is not well studied while more attention to the description of the species and less to the population parameters and intraspecific diversity is paid by gatherers/botanists. The biodiversity of medicinal plants is yet to be well studied in many Asian countries and assumes priority, in view of the extensive destruction of plant rich habitats in tropical conditions. Many of the Asian plant species (Including *Chlorophytum*) yield high value products. However, these species have to be critically studied to categorize varietal differences, conserve the variation and use the superior plants or clones for sustainable use (Batugal et al., 2004). The habitat, habit, growth form, phenology, distribution and other characteristics are documented in Table 1 which has been generated in recent years through many publications highlighting the morphological diversity in the Indian *Chlorophytum* species.

A single discipline is not sufficient to construct the natural group of species within this huge genus. Consequently, it is necessary to bring together data from all possible fields to accomplish satisfactory classification of this rather mistreated genus (Naik and Nirgude, 1981).

3. Seed morphology

Marais and Reilly (1978) studied the generic demarcation of *Anthericum* against *Chlorophytum*. They fortified a demarcation of two genera in tropical Africa after some new combinations mainly based on seed shape. *Anthericum* with unevenly crumpled seeds and *Chlorophytum* with flat or regularly crumpled saucer-shaped seeds. In the genus, *Chlorophytum* seeds are black and angular round outline, vertically flattened, discoid and thin, or flat on one side and convex on the other. The seeds are also irregularly folded. The outer layer of seed coat contains phytomelan due to which seed shows prominent black colour. The epidermal cells are tabular and flattened, convex rounded, more or less hexagonal and sometimes variously papillate (Kubitzki et al., 1998).

Poulsen and Nordal (2005) studied the phenetic analysis of *Chlorophytum* from 166 entities comprised 461 herbarium collections, from which 57 seeds were scanned to inspect the seed surface morphology and testa anatomy.The shape of the seed varies from disc-shaped to deeply cup-shaped, more or less folded. The periclinal walls of the testa cells vary from flat, tile-shaped to convex, in a few cases with prominent papilla. The wide sampling disclosed that seed morphology was chiefly consistent structures.

Table 1
Morphological diversity of *Chlorophytum* species from India.

Distinguishing characters	*C. arundinaceum*	*C. assamicum*	*C. belgaumense*
Habitat	Shady places in moist deciduous forests, Open Hill slopes	Dense mixed deciduous forests	Rock crevices of mountain hills
Habit	Perennial geophytes, 30-60 cm tall	Perennial terrestrial rosulate herb, erect or sub erect leaves to 45 cm long	Perennial geophytes, 15-55 cm tall
Roots	Fibrous, tuberous; tubers fusiform	Rhizomatous rootstock subterranean, horizontal to oblique, narrowly fusiform, white; slender secondary roots mostly produced from below the fusiform area	Fibrous, tuberous; tubers fusiform, tubers terminate with vegetative buds
Leaves	Rosette, sessile, ensiform, strap shaped, glaucous green beneath, 18-28 nerved, apex acute, margin entire to undulate	Sessile, rosulate, spreading, imbricating at base; leaf blade broadly lanceolate, margin entirehyaline, slightly undulate, acuminate, base gradually narrowed down, green, leathery, both surfaces glabrous; veins 24-28, parallel, main vein channelled on upper surface	Radical, sessile, lanceolate, glabrous, subcoriaceaous, 16-22 veined apex acute, margins hyaline, slightly undulate
Scape	Unbranched, without sterile bracts	Solitary, unbranched, peduncle long, terete, glabrous, without intermediate node, raceme	Unbranched, without sterile bracts
Flower	White pedicellate, pedicel jointed at middle or below middle	Perigone segments in two whorls, free, white, ovate lanceolate, obtuse, veins obscure	White, pedicellate, pedicel jointed above middle
Androecium	Stamens 6, Filaments white glabrous, Anthers yellow	Stamens in two whorls Filaments terete, white, glabrous, slightly longer than anthers, smooth; Anthers yellow, dehiscing with one apical pore on each side of the minute terminal appendage, later furrowing below	Stamens 6, Filament white, smooth, minutely papillose, Anthers yellow
Gynoecium	Ovary sessile, green, globose, Style declinate white, Stigma minutely papillose	Ovary terete, light greenish Style terminal, straight, white, glabrous; Stigma elongate, finely papillose	Ovary sessile, green, globose, tyle declinate white, Stigma minutely papillose
Capsule	Green, triquetrous, Obcordate	Green, triquetrous, sulcate	Green to black, triquetrous, Obcordate
Seed	Orbicular, discoid, black, minutely papillose	Not Observed	Orbicular, biconvex, discoid, black
Common Name	Safed Musali (Hindi, Marathi), Ganjagatta (Gond)	-	-
Phenology (Flr & Ftr)	May-November	April-May; May-June	May-June
Distribution	India: Bhutan, Myanmar, India-Chhattisgarh, Jharkhand, Kerala, Madhya Pradesh, Maharashtra, Orissa, Sikkim, Tamil Nadu, Uttar Pradesh, West Bengal	Forests of Behali Reserve Forest, Sonitpur district of Assam in Northeast India	India: Karnataka, Belgaum, Khanapur
*Chromosome count (2n)	28, 40, 42	–	42

Table 1 Continued

Distinguishing characters	***C. bharuchae***	***C. borivilianum***	***C. breviscapum***
Habitat	Arid hilly parts of mountains	Arid hilly parts of mountains, forest covers of moist to dry deciduous forest	shady places along margins of moist deciduous forests and open hill slopes
Habit	Perennial geophytes, 60-80 cm tall	Perennial geophytes, 15-25 cm tall	Perennial geophytes, 15-25 cm tall
Roots	Fascicled, fleshy, evenly thickened, non-tuberous.	Fasciculate, densely clustered on stem disc, sessile, non-tuberous	Roots fibrous, tuberous; tubers numerous, ellipsoid to oblong, towards the end of roots
Leaves	Rosette, sessile, lanceolate, ensiform, lorate, channeled, glaucous beneath, 20-25 veined, apex acute, margin entire, hyaline	Rosette, lanceolate, sessile, glaucous green, cartacious, 12-25 veined, apex acute, margin entire, hyaline.	Rosettes, lanceolate, sessile, rarely pseudopetiolated, dark green, leathery, 11-14 veined, apex acute; margin entire to undulate, hyaline
Scape	Solitary, branched, sterile bracts rarely present	Solitary, unbranched, naked, pubescent to glabrous, without sterile bracts	Unbranched, raceme dense
Flower	White, pedicellate, floral bracts brown at margin, pedicel jointed at the base of flower	White, pedicellate, pedicel jointed below the middle	White, pedicellate, pedicel jointed at the middle or below middle
Androecium	Stamens 6, Filaments white, warty or wavy in texture, Anther much shorter than filaments, yellow	Stamens 6, filaments, white, smooth,Anther long, basifixed, sickle shaped, half the length of filaments, yellow	Stamens 6, Filaments white, glabrous, Anther yellow
Gynoecium	Ovary sessile shortly stalked, green, globose, Style straight - slightly curved in middle, white; Stigma minutely papillose	Ovary sessile, green, globose - triquetrous; style white, curved out from the base and turns inward at the end, stigma minutely papillose	Ovary sessile, green, globose, style declinate, white, stigma minutely papillose
Capsule	Green, triquetrous, Obcordate	Green, triquetrous, Obcordate	Green, triquetrous, Obcordate
Seed	Orbicular, discoid, black, minutely papillose	Orbicular, discoid, black, minutely papillose	Orbicular, discoid, black, minutely papillose
Common Name	Phulbhaji	Safed Musali, Pandhari Musali (Marathi), Shwet Musli (Sanskrit), Dholi Musali (Gujarati), Bhojpuri (Khiruva)	Khodashi
Phenology (Flr & Ftr)	June - August	May-July	May-November
Distribution	India: Maharashtra-Nasik, Kolhapur, Aurangabad. Karnataka-Belgaum	Naturally occur in India -Chhattisgarh, Goa, Gujarat, Madhya Pradesh, Maharashtra and Rajasthan. Commercially cultivated in peninsular India	Bhutan, Myanmar, India-Chhattisgarh, Jharkhand, Kerala, Madhya Pradesh, Maharashtra, Orissa, Sikkim, Tamil Nadu, Uttar Pradesh, West Bengal
*Chromosome count (2n)	16	28	42
Distinguishing characters	***C. comosum***	***C. diwanji***	***C. filipendulum* subsp. *amaniense***
Habitat	Cultivated as indoor ornamental plant. At least six different forms are grown as pot herb in the Indian gardens (Naik 1980)	Forest undergrowth, near streams and in moist and shady places	Grown as foliage ornamental plant
Habit	Perennial geophytes, 15–50 cm tall	Perennial herb, up to 40 cm high	Perennial geophytes 15-25 cm tall

Table 1 Continued

Distinguishing characters	***C. comosum***	***C. diwanji***	***C. filipendulum* subsp. *amaniense***
Roots	Fibrous, tuberous; tubers ellipsoid	Lateral root tubers elliptic-ellipsoid, swollen and tuberous middle, terminating with fascicle of secondary long fibrous roots	Fasciculated, tuberous, tubers ellipsoid to oblong
Leaves	Rosette, sessile, ensiform, variegated, apex acute-mucronate, 12-15 nerved, nerves prominent on lower surface, margin entire	Radical, erect, spreading, sessile, imbricate at base; broadly lanceolate, green above, glaucous white beneath, glabrous, margin slightly serrulate, hyaline, apex acute	Rosettes, elliptic, thick, partially succulent, 21-23 veined, apex acute-acuminate, petiolate, winged orange colored; margin entire to undulate, hyaline; midvein orange-yellow
Scape	Raceme, sparsely flowered	Solitary, unbranched, shorter than leaves, flowers alternate to sub-opposite	Tuft, shorter than leaves, necked, unbranched, without sterile bracts
Flower	White, pedicellate, Pedicel whitish, jointed above the middle	White, pedicellate, pedicel jointed above the middle, upper part thicker, cylindrical, lower part trigonous, in cross section, glabrous	Greenish white, pedicellate, pedicel jointed above middle
Androecium	Stamens 6, Filaments white, smooth; Anther yellow	Stamens 6, connivent, erect; Filaments white, papillose, dilated at base; shorter than anthers; Anthers yellow	Stamens 6, Filaments white papillose, Anthers yellow
Gynoecium	Ovary sessile, green, globose; style long, straight, white; Stigma minutely papillose	Ovary sessile, green, globose; style white, glabrous, declinate, stigma papillose	Ovary sessile green-orange tinted, triquetrous Style white, shorter than or equal to stamens
Capsule	Green, triquetrous	Green, black at maturity, triquetrous, sulcate	Green triquetrous
Seed	Orbicular, discoid, black	Orbicular, discoid, flat, black, granular, shiny	Orbicular, discoid, papery, black, minutely papillose
Common Name	Spider plant, airplane plant or hen-and-chicken's plants	-	Fire flash plant, Fire Glory, Mandarin Plant, Tangerine, Sierra Leone Lily
Phenology (Flr & Ftr)	Jun-November	June-October	Throughout year
Distribution	Ornamental plant	Madhya Pradesh; Khandwa District, Dhama and Golai village.	Ornamental plant
*Chromosome count (2n)	28	-	14
Distinguishing characters	***C. glaucoides***	***C. glaucum***	***C. gothanense***
Habitat	Steep mountain terrain, with harsh climatic conditions like, high winds, rains and mist	Slopes of mountain terrain	Strictly grows on lateritic plateaus
Habit	Perennial geophytes, 30-45 cm tall	Perennial geophytes, 30-65 cm tall	Perennial geophytes 20-35 cm tall
Roots	Fibrous, tuberous; tubers, elongated, elliptic	Fibrous, tuberous; tubers very few, ellipsoid to oblong	Fasciculated, tuberous; tubers fusiform, ellipsoid to oblong
Leaves	Rosettes, lanceolate, sessile pseudopetiolated, dark green above, glaucous green below, leathery, 18-28 veined, ventrally prominently veined, apex acute; margin wavy undulate, hyaline	Rosettes, elliptic-oblong, pseudopetiolated, dark green above, glaucous green below, leathery, 21-28 veined, apex acute; margin wavy - undulate, hyaline	Rosettes, sessile, linear-lanceolate, falcate, green, glaucous green below, 19-21 veined, apex acute; margin wavy-undulate, hyaline, translucent

Table 1 Continued

Distinguishing characters	***C. glaucoides***	***C. glaucum***	***C. gothanense***
Scape	Solitary, unbranched, bracteate, dense raceme	Solitary, unbranched or rarely branched, smooth, bracteate, dense raceme	Unbranched, smooth, shorter than leaves, ebracteate, dense raceme
Flower	White, pedicellate, pedicel jointed above middle or at the base of flower	White, pedicellate, pedicel jointed above middle, swollen at articulation	White, pedicellate, pedicel jointed above middle or at the base of flower
Androecium	Stamens 6, filaments white, papillose, inflated at middle; Anther basifixed, yellow	Stamens 6, filaments, white, papillose, inflated at middle; Anther basifixed, yellow	Stamens 6, filaments white, smooth; Anther yellow
Gynoecium	Ovary sessile, green, globose-triquetrous	Ovary sessile, green, globose-triquetrous	Ovary sessile, green, globose - triquetrous
	Style white, shorter than stamens, straight	Style white, longer than stamens, bends out from base and from the middle parallel to stamens	Style white, declinate
	Stigma minutely papillose	Stigma minutely papillose	Stigma minutely papillose
Capsule	Green triquetrous	Green, triquetrous	Green, triquetrous
Seed	Orbicular, discoid, black, minutely papillose	Orbicular-reniform, discoid, notched at radical, black, minutely papillose	Orbicular, discoid, black, minutely papillose
Common Name	Kapar Musali	Kapar Musali	-
Phenology (Flr & Ftr)	August - December	August-December	August-December
Distribution	Northern Western Ghats of Maharashtra, Goa and Karnataka	India, Goa, Madhya Pradesh, Maharashtra, Karnataka, Satpura ranges, Kalsubai-Harishchandra ranges, Mahadev ranges	Endemic to lateritic plateaus of Northern Western Ghats
*Chromosome count (2n)	42	16, 42	28
Distinguishing characters	***C. heynei***	***C. indicum***	***C. kolhapurense***
Habitat	High humus containing soil and rocky substratum in semi evergreen forest	Rock crevices under shades in the dry deciduous forest	Sandy soils on granite gneiss rocks in scrub forests in open ground around trees and shrubby dry deciduous forest
Habit	Perennial geophytes 15-30 cm tall	Perennial geophytes 20-45 cm tall	Perennial geophyte 20-40 cm tall
Roots	Fasciculated, tuberous; tubers very few, arise at lateral fibrous roots, ellipsoid to oblong	Fibrous, tuberous; tubers very few, ellipsoid to oblong	Fasciculated, fleshy, evenly thickened, non-tuberous
Leaves	rosettes, elliptic, pseudo petiolated, winged dark green, glaucous green below, channeled, thick, partially succulent, 19-23 veined, apex mucronate, margin entire to undulate, hyaline	Rosettes, elliptic-oblong, sessile, rarely pseudo petiolated, glaucous green below, 19-21 veined, apex acute; margin wavy, hyaline	Rosette, sessile, lanceolate, ensiform, lorate, channeled glaucous beneath, 15-21 veined, gradually narrowing apex, apex acute; margin entire, hyaline
Scape	Tuft, shorter than leaves, necked, unbranched, dense raceme	Tall, solitary, unbranched, smooth, naked, fairly dense raceme	Solitary, branched longer than leaves
Flower	Greenish white, pedicellate, pedicel articulated at the tip	White, pedicellate, Pedicels cylindrical, white, smooth, jointed above middle, swollen at articulation	Green, pedicelate, pedicels cylindrical, greenish brown, smooth - warted, jointed at the base of flower

Table 1 Continued

Distinguishing characters	***C. heynei***	***C. indicum***	***C. kolhapurense***
Androecium	Stamens 6, filaments long, white, papillose, inflated at middle Anther basifixed, yellow	Stamens 6, filaments white, papillose, inflated at middle Anther basifixed, yellow to mustard coloured	Stamens 6, filaments, white, warty or wavy in texture; Anther much shorter than filaments, yellow
Gynoecium	Ovary sessile, green, cylindrical-triquetrous Style white, shorter than stamens, straight Stigma minutely papillose.	Ovary sessile, green, globose-triquetrous; style white, longer than stamens, bends out from basen, stigma minutely papillose	Ovary sessile, green, globose style straight-falcate, white sigma minutely papillose
Capsule	Green, triquetrous	Green, triquetrous	Green, triquetrous, obcordate
Seed	Orbicular, discoid, papery, black, minutely papillose	Orbicular-reniform, discoid, notched at radical, black, minutely papillose	Orbicular, discoid, black, minutely papillose
Common Name	-	-	-
Phenology (Flr & Ftr)	November - December	August - December	June-July
Distribution	Endemic to South India, throughout Tamil Nadu and Kerala	Dry hills of Andhra Pradesh, Karnataka and Tamil Nadu	From Kolhapur, Maharashtra to Bodiyanaknur, Theni District, Tamil Nadu
Chromosome count(2n)	14, 28, 56	14, 42, 84	16
Distinguishing characters	***C. laxum***	***C. malabaricum***	***C. nepalense***
Habitat	Adaptable to varied climatic conditions and occurs in diverse ecological habitats.	The Shola forest of high altitude hills	Slopes of valleys as undergrowth
Habit	Perennial geophytes 4-30 cm tall	Perennial geophytes 15-35 cm tall	Perennial geophyte 30-60 cm tall
Roots	fibrous, tuberous; tubers, ellipsoid to oblong	Fasciculated, rarely tuberous tubers very few, ellipsoid to oblong	Fasciculated, fleshy, evenly thickened, rarely tuberous
Leaves	Rosettes or distichous, linear-lanceolate, falcate or ensiform, sessile, dark green above, glaucous green below, 13-15 veined, veins prominent below, apex acute; margin entire, hyaline	all rosettes, elliptic - oblong, sessile, falcate to recurved, green above, glaucous green below, leathery, 19-21 veined, apex acute to acuminate; margin wavy-undulate, hyaline	Rosette, erect, sessile, lanceolate 21-23 veined, gradually narrowing at base, apex acute, margin unites forms con at tip; margin entire, hyaline
Scape	Tuft, branched, rarely unbranched, smooth, naked, lax raceme	2-3 per plant, unbranched or rarely branched, smooth, shorter than leaves, ebracteate, dense raceme	Solitary, branched, sparsely flowered panicle, longer than leaves
Flower	White, pedicellate, Pedicels cylindrical, greenish white, smooth, jointed below middle, swollen at articulation	White, pedicellate, Pedicels cylindrical, white, smooth, jointed above middle	Drooping, white, pedicellate pedicels cylindrical, greenish white, smooth jointed at the middle, swollen at articulation
Androecium	Stamens 6, filaments translucent white, smooth; Anther basifixed, yellow	Stamens 6, filaments white, smooth to papillose, inflated at middle; Anther basifixed, yellow	Stamens 6, connate at apex, erect; filaments white, smooth; Anther nearly double the length of filament, yellow
Gynoecium	Ovary sessile, green, globose-triquetrous style straight, white, longer than stamens; Stigma minutely papillose	Ovary sessile, green, globose - triquetrous style white, straight, included in stamens, stigma minutely papillose.	Ovary sessile, green, globose-angled style straight, white stigma minutely papillose
Capsule	Green, triquetrous	green, triquetrous	Green, triquetrous, obcordate

Table 1 Continued

Distinguishing characters	***C. laxum***	***C. malabaricum***	***C. nepalense***
Seed	Orbicular - reniform, discoid, notched at radical, black, minutely papillose	Orbicular-reniform, discoid, notched at radical, black, minutely papillose India, Karnataka and Kerala	Orbicular, discoid, black, minutely papillose
Common Name	-	-	-
Phenology (Flr & Ftr)	August - December	August-December	July-September
Distribution	Africa, Tropical and Temperate Asia, Australia. India: throughout the country.	India, Karnataka and Kerala	Indian Subcontinent: Assam, Bangladesh, Bhutan, East Himalaya, Nepal, Sikkim. China: Sichuan, Xizang, Yunnan of China; Myanmar; Thailand
*Chromosome count (2n)	14, 16, 32	42	56
Distinguishing characters	***C. nimmonii***	***C. palghatense***	***C. sharmae***
Habitat	Near the water streams under the shades of trees and bushes in moist deciduous to evergreen forest	Grass lands of high mountains	Slopes and margins of shola forests
Habit	Perennial geophyte 35-65 cm tall	Perennial herb, ca. 35 cm tall	Perennial, tuberous herb, c. 35 cm tall
Roots	Numerous, fasciculated, fleshy, evenly thickened, non-tuberous	Fibrous, fasciculated	Cylindrical, forming tubers at distal parts; tubers ellipsoid, terminating with fascicle of secondary roots
Leaves	Rosette, pseudopetiolated, lanceolate to elliptic, glaucous green beneath, 21-25 veined, gradually narrowing at base, pseudopetioled winged apex acute; margin undulate, hyaline	Rosette, spreading, lanceolate, 11-12 veined, sessile, glabrous and dull green above, very small appressed white hairs beneath; margin entire, hyaline, apex acute-acuminate	Radical, erect and spreading, linear, sessile, chartaceous, glabrous, dull green above, glaucous-white beneath; leaf lamina 7-9 nerved; margin translucently serrulate, hyaline; apex acute
Scape	Solitary or branched, necked, sparsely flowered panicle, longer than leaves	Solitary, unbranched, bracteate, flowers in alternate to sub-opposite	Solitary, unbranched or rarely branched, bracteate or rarely ebracteate, flowers in alternate to subopposite
Flower	Drooping, white, pedicellate, Pedicels cylindrical, greenish white, smooth, jointed at the below middle	White, bracteate, pedicellate, Pedicel articulation swollen, cylindrical, glabrous	White, pedicellate; bract large, triangular, acute at apex; pedicel articulated above the middle
Androecium	Stamens 6, connate, erect; Filaments white, smooth; Anther much longer than filaments, yellow	Stamens 6 divaricated; Filaments longer than the anthers, smooth, white; Anthers 3.1-3.2 mm long,obtuse, dull yellow	Stamens 6, divaricate; Filaments long, white, smooth, longer than the anthers; Anthers dull yellow, apiculate
Gynoecium	Ovary sessile, green, globose; Style long, straight, white Stigma minutely papillose.	Ovary 1.5-2 mm long, elliptic, sessile, glabrous, green; septal nectaries conspicuous; Style 6-6.2 mm long, straight, persistent, white; stigma glabrous	Ovary turbinate, sessile, green; septal nectaries present; Style not curved, persistent, white stigma minutely papillose
Capsule	Green, triquetrous, obcordate	Triquetrous	Green, triquetrous
Seed	Orbicular, discoid, black, minutely papillose	Reniform, discoid, black seed testa granulate	Orbicular, discoid, black
Common Name	-	-	-

Table 1 Continued

Distinguishing characters	***C. nimmonii***	***C. palghatense***	***C. sharmae***
Phenology (Flr & Ftr)	July-November	September-November	October-December November-January
Distribution	Western Ghats of Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu and East Godavari District of Andhra Pradesh	Palamala hills of Dhoni forest and Elival hills of Muthikulam forests of Palakad District of Kerala	India, Kerala
*Chromosome count (2n)	42	-	42
Distinguishing characters	***C. tillariense***		***C. tuberosum***
Habitat	grows at high altitudinal lateritic plateaus are iron-rich duricrusts with an elevation range between 680 and 745 m		Varied climatic conditions and occurs in diverse ecological habitat
Habit	Perennial herb, up to 30 cm high, growing in clumps		Perennial geophytes 8-30 cm tall
Roots	Rhizome short, Root tubers sessile, fusiform, many fibrous roots present on root tubers.		Fibrous, tuberous; tubers, ellipsoid to oblong
Leaves	Radical, distichous, sessile, imbricate at base; narrowly elliptic to ensiform, glabrous, subcoriaceous, channelled, 16-20 veined, midvein distrinct, apex acute, margins hyaline, entire.		Rosettes, sessile, linear-lanceolate, falcate, recurved, dark green above, glaucous green below, 09-13 veined, veins prominent below, apex acute; margin undulate-entire, serrulate, hyaline
Scape	Solitary, unbranched, naked, usually longer than leaves, thick, terete, erect, originating in the axil of a leaf. Inflorescence a raceme		Tufts, unbranched, rarely branched, smooth, naked, dense raceme
Flower	Flowers rachis visible in fruiting, nodes spirally arranged in clusters. Bracts triangular,white, subtending a single smaller bract, persistent until fruit formation, apex acute, margin hyaline. long, glabrous, jointed near the middle, Perianth white, star-shaped,Tepals 6, in two whorls, ovate-lliptic, 5(7)-nerved, apex acute, papillose, margins hyaline		White, pedicelate, sweet scented, Pedicels cylindrical, greenish white, smooth, jointed below middle, swollen at articulation
Androecium	Stamens 6, androecium radially symmetrical, opposite to the style, connivent, erect; Filaments long, white, linear throughout, two times longer than the anther, smooth, linear, yellow, dehiscing by longitudinal slits		Stamens 6, erect, introse filaments white, smooth; Anther basifixed, yellow, recurve after dehiscence
Gynoecium	Ovary sessile, globose, green; style declinate; stigma minutely papillose at apex.		Ovary sessile, white, turbinate, cylindrical-triquetrous; style declinated, white, longer than stamens, turns away from the base and form sharp curvature at tip stigma minutely papillose
			Green, triquetrous
Capsule	Capsule triquetrous to 3-sulcate, obcordate, veined, green when young, brown at maturity. Seeds 1-3 in each cell		
Seed	Orbicular, discoid, black; testa verrucose, shiny		Orbicular-reniform, discoid
Common Name	-		-
Distinguishing characters	***C. tillariense***		***C. tuberosum***
Habitat	Grows at high altitudinal lateritic plateaus are iron-rich duricrusts with an elevation range between 680 and 745 m		Varied climatic conditions and occurs in diverse ecological habitat
Habit	Perennial herb, up to 30 cm high, growing in clumps.		Perennial geophytes 8-30 cm tall

Table 1 Continued

Distinguishing characters	*C. tillariense*	*C. tuberosum*
Roots	Rhizome short, Root tubers sessile, fusiform, many fibrous roots present on root tubers	Fibrous, tuberous; tubers, ellipsoid to oblong
Leaves	Radical, distichous, sessile, imbricate at base; narrowly elliptic to ensi-form, glabrous, subcoriaceous, channelled, 16-20 veined, midvein dis-trinct, apex acute, margins hyaline, entire.	Rosettes, sessile, linear-lanceolate, falcate, recurved, dark green above, glau-cous green below, 09-13 veined, veins prominent below, apex acute; margin undulate-entire, serrulate, hyaline
Scape	solitary, unbranched, naked, usually longer than leaves, thick, terete, erect, originating in the axil of a leaf. Inflorescence a raceme	Tufts, unbranched, rarely branched, smooth, naked, dense raceme
Flower	flowers rachis visible in fruiting, nodes spirally arranged in clusters. Bracts triangular,white, subtending a single smaller bract, persistent until fruit formation, apex acute, margin hyaline. long, glabrous, jointed near the middle, Perianth white, star-shaped,Tepals 6, in two whorls, ovate-lliptic, 5(7)-nerved, apex acute, papillose, margins hyaline	White, pedicelate, sweet scented, Pedicels cylindrical, greenish white, smooth, jointed below middle, swollen at articulation
Androecium	Stamens 6, androecium radially symmetrical, opposite to the style, connivent, erect; Filaments long, white, linear throughout, two times longer than the anther, smooth, linear, yellow, dehiscing by longitudinal slits.	Stamens 6, erect, introse, Filaments white, smooth; Anther basifixed, yellow, recurve after dehiscence
Gynoecium	Ovary sessile, globose, green; style declinate; stigma minutely papillose at apex.	Ovary sessile, white, turbinate, cylindrical-triquetrous; Style declinated, white, longer than stamens, turns away from the base and form sharp curvature at tip stigma minutely papillose
Capsule	Capsule triquetrous to 3-sulcate, obcordate, veined, green when young, brown at maturity. Seeds 1-3 in each cell	Green, triquetrous
Seed	Orbicular, discoid, black; testa verrucose, shiny	Orbicular-reniform, discoid
Common Name	-	-
Phenology (Flr & Ftr)	July to August	June-August
Distribution	The species grows on high altitudinal lateritic plateaus at Tillari region in Kolhapur District of Maharashtra	East Tropical Africa. Asia Tropical-China, India, Nepal, Myanmar, Sri Lanka. In India occurs throughout
*Chromosome count (2n)	-	16

*Chromosome count (Lekhak et al., 2012: Adsul 2015).

Bjora et al. (2008) investigated African species in which SEM study discovered noteworthy differences. Meerts and Bjora (2012) revised genus *Chlorophytum* for the Democratic Republic of the Congo, Rwanda and Burundi, for the dealing of the genus for the *Flore d'Afrique Centrale*. In this study, scanning electron microscopy was used for the seeds of fourteen taxa. In the case of Indian species, Adsul (2015) tried to solve the species complexes and investigated 14 species. In this investigation SEM characters *viz*. Testa cells, their arrangement, the distance between periclinal walls of Testa cells and papillae on the Testa cells were used to distinguish closely related species.

Nalawade et al. (2020) analysed Seed morphology of 19 species of *Chlorophytum* collected from India. The seeds are disparate in shape, size, colour, weight, surface architectural pattern, and hilum types. Identification key is also prepared by using these different characters. Taxonomic significance and phenatic similarities of the seed morphological features were strongly suppoted by this analysis.

4. Anatomical studies

Most of the *Chlorophytum* species are usually forest dwellers and ephemerals making it difficult to find them in flower and fruit (Chandore et al., 2012). The restricted distribution, remote habitat, seasonal flowering and fruiting period, most of the species with similar sized flowers and leaf pattern and identification

key with overlapping characters have made the genus difficult to identify (Adsul et al., 2014). Naik and Nirgude (1981) have studied the anatomical features, together with stomatal characters in 16 Indian and African taxa of *Chlorophytum* and specified their part in Taxonomy of genus. Whereas, Patil and Patil (1987) studied 8 species of *Chlorophytum* and three varieties of *C. comosum* for the traits like stomatal distribution, frequency, index and size which showed that the stomata are predominantly on the lower surface and without subsidiary cells in all *Chlorophytum* species investigated. *Chlorophytum tuberosum* showed the occurrence of stomata on the upper surface which can be employed for taxonomic delimitation. Nalawade and Gurav (2017) investigated 16 species of *Chlorophytum* to know the size, structure and distribution of epidermal cells, stomata, stomatal density and stomatal index.

5. Plant breeding and cultivation practices

Utilization of herbal medicines is prevalent and growing. Loss of genetic diversity and destruction of habitat occurs due to harvesting from the wild as the chief source of raw material. To conquer the difficulties which are deep-rooted in herbal extracts *viz.* wrong identification, genetic and phenotypic variability, extract variability and uncertainty, toxic components and impurities, the domestic farming is a worthwhile alternative. Cultivation under the controlled environments can overcome problems and also helps to manipulate phenotypic discrepancy in bioactive compounds and toxins. Agronomic and medicinal traits can be improved by conventional plant-breeding and molecular marker-assisted selection will be used gradually. Problems for the successful commercial cultivation of medicinal plants comprises the concern of predicting which extracts will remain saleable and the likely market preference for what is seen as naturally sourced extracts (Canter et al., 2005).

For the calibration of drug safed musli, accurate botanical identification is required. Aundhe and Deokule (2001) collected ten species of *Chlorophytum* from various places of Maharashtra and identified based on their root morphology and classified by preparing Key of root tubers. Safed Musli (*C. borivilianum*) cultivators are facing a lot of difficulties, these include the lack of information on the package of cultivation practices, high rate of seed material and unavailability of an effectual and cost-effective technology for the peeling of roots. Therefore, a need to collect information on various aspects of Safed Musli (*C. borivilianum*) cultivation is essential. In this regard, Singh et al. (2003) carried out research on cultivation practices at CIMAP, Lucknow and other research centers in India which will help in future agronomic research. The importance of Plant Genetic Resources (PGR)-related activities was recognized under the All-India Coordinated Research on Medicinal and Aromatic Plants and National Research Center for Medicinal and Aromatic Plants (NRCMAP) maintained 52 valuable stocks of Safed musli. The evaluation and characterization of these accessions are in a continuous process (Batugal, 2004).

The constant attenuation of natural populations led to the cultivation of *C. borivilianum* and necessitates genetic improvement. Kumar et al. (2010) characterized and quantified genetic variability between 31 genotypes by means of nine characters of *C. borivilianum* of indigenous derivation via Mahalanobis D^2 statistics. The grouping pattern stated that geographical diversity was not essentially linked by means of genetic diversity. The D^2 and correlation study suggests that for the root yield in *C. borivilianum* the diversity for leaf number, leaf length and finger number could be reliable selection standards.

Mishra and Kotwal (2010) collected raw samples of safed musli from Dhamtari market, Chhattisgarh existing malpractices and ocular analysis specify that both deliberately and accidentally musli tubers are adulterated. The stakeholders misconducts selling of musli along with genuine material and sometimes dried roots of unlike species. The poor quality is due to early root harvesting, mis-identification of species, mixing of similar species etc. The study recommends sustainable harvesting and disc with some tubers for future rejuvenation. Study also suggested some procedures to fight adulteration problem in the raw material trade.

An extensive shrinking of natural resources focused on the cultivation of *Chlorophytum borivilianum* and has needed the genetic improvement program. Dwivedi (2013) studied genetic variance between 9 genotypes from Chhattisgarh natural habitats and characterized for ten quantitative and four qualitative traits. The results revealed that plant morphology needs to be determined to recognize the morphological markers that not only simplify comprehensive screening of germplasm lines but also helpful in the discovery of the specific genotype.

Bodele (2016) studied the cultivation of eleven species of *Chlorophytum*. Forest dweller species gathered in the month of June and July and cultivated with the various ratio of soil, sand and farmyard manures. The plant needs warm humid conditions with good drainage arrangement which enables healthier tuber production. Vegetative propagation gives the best result than seed germination method. The best season for cultivation reported between June to July and for harvesting from October to December.

In India three important species viz. *C. arundinaceum, C. tuberosum* and *C. borivilianum* are commercially utilized. Vital tonics are prepared from their raw material which is used to cure general frailty. In the trade unprocessed source of medicine is quite perplexing. Meanwhile, *Asparagus adscendens* Roxb. is also well traded for a similar reason. Some tribal communities from Gujarat and Madhya Pradesh use the *C. borivilianum* as a leafy vegetable while most of the other species of *Chlorophytum* are forest dwellers (Maiti and Geetha, 2005; Chandore et al., 2012). The Medicinal Plant Board, Government of India, has recognized Safed Musli as the 6th important herb to be protected and promoted. The Board inspires conventional farming of Safed Musli by the farmer by prolonging a subsidy of 20% through the National Horticultural Board on Project cost (Agricare 2005-2006).

Genus *Chlorophytum* fortifies its place predominantly as marketable plants with an inclusive range of

applications, from pharmacological to ornamental, with optimistic profitability also. Few species are concerned as ''threatened plant category'' at present day. Great tasks are linked with its traditional propagation approach. The success and swiftness in the propagation of few species of *Chlorophytum* have always been a key concern for farmers and scientists (Chauhan et al., 2016).

6. Molecular approaches for genetic diversity

Molecular approaches have turned out to be a crucial portion of maximum studies on genetic diversity and distribution in the analyses of breeding systems, bottlenecks and other attributes disturbing genetic diversity forms. The studies may use RFLPs, RAPDs, AFLPs or SSRs. It is important, however, to understand that different markers have different properties and will reflect different aspects of genetic diversity (Karp and Edwards, 1995). Poulsen and Nordal (2005) raised the question about African rain forest *Chlorophytum* that, 'why species delimitation is so difficult?' First possibility spring to mind that the species have evolved through a current entry to the forest environment and the speciation process is underway, or the second possibility that the species have altered numerous times to the forest environment and is the selective pressure of shade and high humidity which resulted in apparent identical morphology. The documented wide distribution of most taxa united with poor dispersion capability appears to substantiate well with the second choice. This well exemplified morphometric analysis suggests molecular analysis for the delimitation of species.

Safed Musli which is a crucial aphrodisiac herb, which forms an essential ingredient of the preparation of more than hundred Ayurvedic preparations. Species belonging to both the genera *Chlorophytum* and *Asparagus* are equally treated as aphrodisiac under the name 'Safed Musli' on the basis of their whitish tuberous roots. Misra et al. (2006) studied the AFLP based experiments for the detection of adulterants in crude drug preparations of the 'Safed Musli' complex and resolved the certification problem predominant in the herbal drug marketplace.

Bjora et al. (2008) described six new taxa from southern tropical Africa on the basis of the sister group relationship by cladistic analyses of nuclear and chloroplast DNA sequences. The morphological, molecular and ecological studies of two forest *Chlorophytum* taxa on Mount Kilimanjaro, Tanzania by Bjora et al. (2008) concluded that the two forms of *C. comosum* both are eligible to species recognition. The high-altitude form referred to *C. comosum,* while the low altitude form as a new species *C. rhizopendulum*. The two species were easily distinguished morphologically. Molecular analysis revealed that *C. comosum* is of polyphyletic origin, and the species complex needs review.

Katoch et al. (2010) studied the molecular profiling in plants of five species of *Chlorophytum* (*C. borivilianum, C. arundinaceum, C. laxum, C. capense* and *C. comosum*) by using RAPD marker, the sequences of plastid ribulose bisphosphate carboxylase (rbcL) region, the gene rpl16 and the rpl16-rpl14 spacer region. The spacer region had recognized only two species *viz. C. borivilianum* and *C. comosum*. While RAPD markers and the sequences of rbcL region signify good diagnostic resources for discrimination and proper identification of *Chlorophytum* species from commercial herbal products which eventually certify the reproducibility and the efficacy of herbal drugs.

The RAPD markers were used by Garg (2010) to investigate genetic variability among the seven genotypes of *Chlorophytum borivilianum* from Rajasthan, Madhya Pradesh, Gujarat and Uttar Pradesh. The homology among the seven accessions was studied by fifteen RAPD primers and dendrogram was constructed by using UPGMA. This scenario of genetic diversity offered for *Chlorophytum* species and variants will be beneficial for the conservation of their germplasm and breeding of novel varieties.

The genetic diversity regarding nine genotypes of *C. borivilianum* collected from different geographical areas of Madhya Pradesh, Uttar Pradesh and Chhattisgarh were evaluated by Dwivedi and Sharma (2011). The data reveals a high degree of polymorphism. The highest resemblance value was observed amid Lamni (C.G.) and Chitrakoot (U.P.) genotypes, correspondingly. The studies were carried out by Samantaray et al. (2011) for identification and to establish genetic relationships in *C. arundinaceum, C. tuberosum* and two high yielding genotypes of *C. borivilianum* using RAPD markers. The results revealed that the RAPD markers have the potential for identification and characterization of genetic relatedness among the species and genotypes.

The AFLP analysis was used by Tripathi et al. (2012) to evaluate the genetic similarity among 34 accessions of *C. borivilianum* collected from various parts of Central Indian forests. The cluster analysis formed on the basis of AFLP data revealed partial genetic variation within accessions. The narrow genetic base noticed in *C. borivilianum* probably because of the vegetative propagation and the spontaneous mutation could be responsible for whatever variability present. Knowledge of diverse forms and specific genetic distance evaluations might rise the efficiency of *C. borivilianum* genetic upgrading in India. Tripathi also suggested the further necessity of elucidation of the genetic base for morphological and biochemical traits.

Chlorophytum borivilianum is an important threatened medicinal herb designated as 'Rare' in Red Data Book of Indian plants. The genetic diversity in six genotypes of *C. borivilianum* collected from various geographical areas of Rajasthan, Madhya Pradesh and Jharkhand were assessed by Kumari et al. (2014) using RAPD markers. The investigation revealed a high degree of polymorphism. RAPD marker will have an impact on vigorous germplasm selection and its preservation. It is also suggested that wide-ranging study of genetic diversity together with maximum collections and cognizance of the public about the status, the value of conservation and sustainable consumption of this plant genetic diversity should be promoted.

The genetic diversity, population structure and phylogenetic relationship between *Chlorophytum* species from India were studied by using Amplified

Fragment Length Polymorphisms (AFLP). A high level of genetic diversity was observed. Cluster analysis with the support of morphological information resolved the species in different clusters. The positive correlation between genetic and geographic distance was also observed. The data will be useful in the identification, validation, and conservation of the species (Patil et al., 2015).

Patil et al. (2016) studied 19 species of *Chlorophytum* for authentication and current phylogenetic relationship by using DNA barcoding. In all, 107 accessions were analysed with eight plastid (matK, rbcL, trnH-psbA, rpoC1, ycf5, rpoB, ATP and psbK-psbI) and six nuclear (ITS) markers. The matK and rbcL were found to be ideal markers. The cytological, morphological and genetic data were also used to study phylogeny and credible evolution of the genus.

Kale (2016) investigated 17 species of *Chlorophytum* from India on the basis of morphology, nucleotide sequences of coding, noncoding region, AFLP and generated a DNA barcode for the identification of species at the genetic level. The DNA barcode using *rbcL* nucleotide sequences was highly efficient for the discrimination of *Chlorophytum* species. The phylogenetic analysis was performed by using PAUP analysis and Bayesian inferences of the ten nucleotide sequences (*rcbL*, *atpB-rbcL, ITS, trnLF, trnTL, rpoB, rpoC1, atpF-atpH, accD, psbA-trnH*) and AFLP. In which *rbcl, trnLF, psbA-trnH* and AFLP found to be useful for DNA barcode and the phylogenetic analysis of *Chlorophytum* species. The genetic relationship of the African and Asian species of *Chlorophytum* was also studied by *trnLF* nucleotide sequences which showed sharing of genetic relationship and distribution of species on the basis of the climatic zone.

In past decades there is a resurgence of herbal-based health care which showed an effective increase in the trade of raw drugs. Precise and rapid detection is key to the success for the industry of herbal drug. The traditional approach with expert taxonomist and his modern techniques for accurate identification are time-consuming and lingering for bulk identification at inductrial scale. On the other hand DNA Barcode offers alternate and feasible tool box for it. For the unambiguous identification and to discover new cryptic species the barcode loci must have sufficient information to differentiate closely related plant species. For this Mishra et al. (2016) suggested matK, rbcL, trnH-psbA, ITS, trnL-F, 5S-rRNA and 18S-rRNA DNA Barcodes. They also suggested that, DNA barcoding must be used in concurrence with metabolomics along with need-based transcriptomics and proteomics for effectively resolving authentication challenges in the herbal market.

Similarly, Kale and Deogade (2016) reported 'DNA barcoding' as a promising tool with the special example of controversy between *Asparagus adscendens* and *Chlorophytum borivillianum*. In the ancient text, both these species were described as 'Safed Musli' and commonly used. But both these species have similar morphology and different medicinal properties. The Advance DNA barcoding does not underrate the conventional approach of identification but encourages ancient knowledge for its crucial role in the identification and authentification of medicinal plants.

Bjora et al. (2017) studied the sister group relations of Ethiopian species of *Anthericum* and *Chlorophytum* and variation patterns in the *Chlorophytum gallabatense* Schweinf. ex Baker and *C. comosum* complexes by means of molecular phylogenetic analyses, morphological study, and seed micromorphology by scanning electron microscopy. The previous morphological conclusions support this molecular analysis and that speciation has occurred repetitively within different subclades of genus *Chlorophytum* and at the minimum thrice in genus *Anthericum*.

7. Phytochemical diversity and qualitative and quantitative analysis of phytochemicals

Plants are the source of numerous valuable drugs of natural origin. Analysis of elements and phytochemicals in the wild edible plants plays a decisive role in assessing their nutritional significance (Pandey et al., 2006). Scanty reports are available on the role of micronutrients (Bonnefont-Rousselot, 2006; Rajurkar and Pardeshi, 1997). The relation between an elemental content of medicinal plants and their curative ability is not yet properly explained in terms of modern pharmacological concepts. So, to know the pharmacological action and for the determination of efficiency of medicinal plants for treating different diseases there is need of quantitative estimation of various trace elements (Rajua, 2006). The disparity in human health is either due to extra or lack of trace elements in animals, plants, soils and water. The proper intake of diets that are excessively high in a particular trace element can influence changes in the functioning, forms and activities of some organs or concentrations of such element in the body tissue and fluids can rise above the permissible limit (Obiajunwa, 2002).

A number of *Chlorophytum* species are pharmaceutically significant. In the nutritional management of bodybuilders and sportsman, their use is widespread and beneficial because of the important phytochemical constituents (Thakur et al., 2009). The phytochemical diversity, medicinal properties and uses of *Chlorophytum* species are mentioned in Table 2. The roots are reported to contain 42% of carbohydrates, 8-9% of proteins and 2-17% of saponins (Bordia et al., 1995). The important plants of the genus like *C. borivilianum, C. malayense, C. comosum,* and *C. arundinaceum* have steroidal saponins which are paying attention and courtesy because of their structural diversity and healing ability (Sharma et al. 2012).

In the assessment of chemical analysis of *Asparagus officinalis* and *Chlorophytum comosum* from Iranian plant foods, Aberoumand (2010) confined that the root tubers of *C. comosum* contain carbohydrates (65.84%), crude protein (4.54%), crude fat (2.00%) and mineral material (10.38%). The roots of *C. comosum* could be a virtuous supplement of nutrients like carbohydrates and calcium. The *C. borivilianum* contain a good amount of minerals *viz.* Calcium (201.04 ± 0.29 mg/100g), Potassium (706.98 ± 0.75 mg/100g), Magnesium (85.29 ± 0.16 mg/100g) and sodium (48.92 ± 0.06 mg/100g)

on dry weight basis, hence can also be convenient for food bio-fortification (Bhat et al., 2010). The *C. borivillianum* has got a good market demand all over the world particularly in the Gulf nations and the West. The intellect of ancient India revealed that the Safed Musli is an exclusive, powerful and effective medicine. Alim et al. (2010) reported indirect value addition of the crude material and also the processed products by integrating some quantities through the period of handling and processing of crude material and Phytoformulation of the herbal drug for naturalness and the quality. The study also indicated the assessment of the metal contaminants in accordance with AYUSH and WHO approvals which has become mandatory for export purpose.

Sriram et al. (2012) carried out introductory phytochemical screening and Atomic absorption spectroscopy of the root extract of *C. borivilianum* to determine the mineral content, secondary metabolites and antibacterial property. These results showed that *C. borivilianum* has a maximum inhibition against *Staphylococcus aureus* followed by *Escherichia coli*, *Pseudomonas aeruginosa* and *Bacillus cereus*. Results obtained provide ample proof for the use of *C. borivilianum* as phytomedicine and chemosynthetic pharmaceutical research for the development of antimicrobial therapies with less or no side effects.

Bodele (2016) analysed the nutritional value of leaves of *Chlorophytum borivilianum, C. tuberosum* and *C. arundinaceum* which are used as a green vegetable by tribal people. Preliminary phytochemical tests for organic and inorganic constituents from twelve species of *Chlorophytum* were also analysed in which the major component saponin was observed maximum in *C. breviscapum*. The highest percentage of protein was detected from leaves of *C. arundinaceum* and it can be acclaimed as a nutritious, green leafy vegetable. Maximum fiber content was in *C. glaucoides*, whereas highest carbohydrate content was observed in *C. kolhapurense* leaves. Nalawade and Gurav (2017) analyzed the proximate composition and elemental content from roots of 17 species of *Chlorophytum* from the Western Ghats. A total of 13 elements N, P, K, Ca, Mg, S, Na, Zn, Fe, Cu, Mn, Mo and B have been measured. In proximate analysis percentage of moisture, ash, crude protein, crude fats and carbohydrate were determined using standard methods. Chief saponin content is found in *C. gothanense* (13.2 ± 0.3%) while lowermost in *C. filipendulum* subsp. *amaniense* (2.95 ± 0.3%).

Patil and Deokule (2010, 2011) and Patil et al. (2011) carried out the study to eliminate the controversy and for botanical calibration thorough pharmacognostic assessment of the tuberous roots of *C. bharuchae*, *C. breviscapum, C. glaucum and C. tuberosum*. The macroscopic and microscopic characters, histochemistry and phytochemistry were studied. The starch, sugar, protein, tannins, glycosides alkaloids and saponins were confirmed by phytochemical and histochemical tests which include percentage extractives, ash and acid insoluble ash and fluorescence analysis. HPTLC technique was used to confirm phytochemical screening of saponins, steroids and stigmasteroids. The *C. borivilianum* was studied for pharmacognostic evaluation, standardisation and pharmaceutical evaluation of mucilage, phytochemical and antimicrobial study (Deore and Khadabadi, 2009; Chakraborthy, 2009; Chakraborthy and Aeri, 2009, 2010; Panda et al., 2010).

Phurailatpam et al. (2009) studied the HPTLC analysis of fasciculated root extract of *C. borivilianum* and *C. arundinaceum*. The results showed similarity in majority of bands in both the species. This similarity can be useful for the cultivation of *C. arundinaceum* as an alternative source to *C. borivilianum* which decreases the collection pressure of *C. borivilianum* from wild habitats. The market samples of Shatavari (*Asparagus racemosus*) are regularly replaced by Safed Musali, though only Shatavari is official in Ayurvedic Pharmacopoeia of India. In this regard a detailed study of Shatavari and Safed Musali (*Chlorophytum arundinaceum*) roots was performed by Sidapara et al. (2013), including morphological study, qualitative and quantitative microscopic evaluation, phytochemical screening and Thin-layer Chromatography (TLC) studies. This work can serve as a very useful phytopharmacognostic tool in the calibration of the raw material and preparations of Shatavari and recognition of its replacement by Safed Musali. which will be beneficial for herbal industries, traditional therapists and for the people who consume Shatavari.

The sensitive and quick HPLC method was developed by Joshi et al. (2013) for the quantification of furostinol and spirostenol type of steroidal saponins. Dwivedi (2013) carried out HPLC analysis for saponin content among the different wild accessions of *C. borivilianum* from forest regions of Chhattisgarh and its adjoining regions. The analysis showed that the highest content of saponin was found in Kawardha region followed by Kewachi. This data will be useful for cultivation and breeding prospect in future. Kaur et al. (2015) carried out saponin content and type of saponins in the tubers (without peels), peels of tubers, leaves and seeds by standard procedures. Thin layer chromatography was used to recognize the types of saponins. Highest yield (%) of crude saponins was found in peel methanol extract, while water extract of tuber showed least saponin content and also confirmed the furostenol and spirostenol saponins by TLC in *C. borivilianum*.

The comparative pharmacognostic, phytochemical and biological estimation parameters between five *Chlorophytum* species were established by Deore et al. (2015). The parameters evaluated are excellent pharmacognostic standards for future relative identification and validation of particular species. Thakre et al. (2016) recognized that the crude methanolic extract of *C. kolhapurens* and *C. bharuchae* species showed excellent antimicrobial activity as compared to active compound extract and it is attributed due to the presence of various phytochemicals. The phytochemical screening was also confirmed by HPTLC analysis for saponins.

The HPTLC fingerprint analysis of a methanolic extract of tubers of 12 *Chlorophytum* species was performed

Table 2
Phytochemical Diversity, Medicinal properties and uses of *Chlorophytum* species.

Name of the species	Phytochemical diversity	Medicinal Properties and uses
C. arundinaceum	1. Stigmasterol, stigmasterol-β-D-glucopyranoside, nonacosane, tetracosanoic acid, triacontanoic acids, 4-hydroxy-8,11-oxidoheneicosanol, pentacosyl docosanoate, tokorogenin, neogetogenin,stigastrol, and glycosides like arundinoside-A and arundinoside-B (Tandon et al., 1992; Tandon and Shukla, 1992, 1996, 1997). 2. Bibenzyl Xyloside (Tandon, 1993) 3. Spirosta-steroidal saponins, spirosta-steroidal alkaloids and galactoglucan oligosaccharides (Ghosal, Shibnath 2006)	1. The root with turmeric is given inrheumatism (The wealth of India, 1950). 2. Root powder after frying in ghee is used for chewing in case of aphthae in mouth and throat (Asolkar et al., 1992) 3. In Ayurveda for treatment of arthritis, rheumatism, and as an aphrodisiac agent (Kirtikar & Basu, 1994). 4. The 50% alcohol extract showed significant antiulcer activity (Rachchh et al., 2004) 5. Fleshy roots are used for the preparation of herbal vital tonics. The species has the same medicinal value as *C. borivilianum* (Maiti, 2005) 6. Most effective as an obesity control agent, health restorative and health promotional (Ghosal , Shibnath 2006) 7. Cooked as a vegetable (Kayang, 2007). 8. Antimicrobial and Antifungal activity (Valya et al., 2009) 9. Its roots are eaten or dried and made into powder taken as a general health and strength tonic, and specifically, to help impotency. Root powder used in Impotency (Nath and Kumar, 2010). 10. Largest source of saponin in Madhya Pradesh and Melghat it is traditionally used as an aphrodisiac (Adsul, 2015).
C. belgaumense	1. 1-Tetradecanamine, N,N-dimethyl, 2-furancarboxaldehyde, 5-(hydroxymethyl), 1-amino-2,6-dimethylpiperidine, 2-cyclopenten-1-one, 2-hydroxy, 1H-tetrazole, 1-methyl, formic acid, ethenyl ester (Shinde et al., 2016)	1. Rarely used by local people as veterinary medicine on Stomach disorder (Adsul, 2015).
C. bharuchae	1. Starch, protein, tannin, saponin, fats, sugars, glycosides, alkaloids (Patil and Deokule, 2010) 2. **Dibutyl phthalate, 2-butenedioic acid (Z)-, dibutyl ester, Benzoic acid, 4-ethoxy-, ethyl ester, DL-Proline, 5-*oxo*-, methyl ester, Hydroquinone (Shinde et al. 2016)	1. Large sized plant and can produce can produce large amount of biomass If the species is proved to be aphrodisiac then it be important source of saponins (Adsul, 2015).
C. borivilianum	1. *O*-β-D-fructofuranosyl-(2→1)-(β-Dfructofuranosyl) *n*-(2→1)-α-D glucopyranoside (Narasimhan et al., 2006)	1. Used in many Ayurvedic vital tonics and aphrodisiac formulations (Maiti and Geetha, 2005).

Table 2 Continued.

Name of the species	Phytochemical diversity	Medicinal Properties and uses
	2. 25 alkaloids, vitamins, proteins, carbohydrates, steroids, saponins, potassium, calcium, magnesium, phenol, resins, polysaccharides (Alim et al., 2010)	2. Extract can be used as adaptogen, in improving or enhancing aphrodisiac activity, reducing stress, increasing nitric oxide level, male sex harmones, preventing age, and treating or preventing sexual dysfunction (Jaykumar et al., 2008). 3. Larvisidal and anthelmintic properties (Deore and Khadabadi, 2009, 2010). 4. Important ingredient of more than a hundred Ayurvedic, Allopathic, Homeopathic and Unani medicinal preparations. It is one of the chief ingredients of Ayurvedic "Chyawanaprash". As a (protein rich) food supplement (Alim et al., 2010). 5. Anti-tumour, Anti-mutagenic and Chemomodulatory Potential (Kumar et al., 2010). 6. Wide range of antibacterial properties (Sundaram, 2011). 7. Roots are medicinally important and proved to be antistress, analgesic, aphrodisiac, immunomodulatory, anti-inflammatory, antidiabetic and antioxidant, Leaves are used as vegetables (Adsul, 2015).
C. borivilianum	1. Borivilianoside-A, borivilianoside-B, borivilianoside-C, borivilianoside-D, borivilianoside-E, borivilianoside-F, borivilianoside-G, borivilianoside-H (Acharya et al., 2008, 2009; Joshi, 2013)	
	2. Sterol stigmasterol, chlorophytoside-I (Deore and Khadabadi, 2010)	
	3. Stigmasterol and hecogenin (Bathoju and Giri, 2012)	
	4. Squalene, 9,12-octadecadienoic acid, methyl ester, 1-nonanamine, N,ndimethyl, phenol, 2,4-bis(1,1-dimethylethyl), 1,3-propanediol,2- (hydroxymethyl)-2-nitro, L-phenylalanine, methyl ester, DL-proline, 5-oxo-, methyl ester (Shinde et al., 2016)	
	5. 1′-acetoxychavicol (Chua et al., 2017)	
C. breviscapum	1. Starch, proteins, reducing and non-reducing sugars, saponins, fats, tannin, glycoside and alkaloids (Patil and Deokule, 2010)	1. It is used as a nutritive and health promoting, immunoenhancing, hepatoprotective, antioxidants. The tubers are used as a medicinal expectorant in fever, leucorrhoea also as a galactagogue and aphrodisiac (Patil and Deokule, 2010).

Table 2 Continued.

Name of the species	Phytochemical diversity	Medicinal Properties and uses
C. comosum	1. Gitogenin, hecogenin, tigogenin, gitogenin glycosides, hecogenin three new spirostanol pentaglycosides Embracing /β-D-apiofuranose (Mimaki et al., 1996) 2. 1-Nonanamine, N,N-dimethyl, 2-furancarboxaldehyde, 5-(hydroxymethyl), 1-amino-2,6- dimethylpiperidine,2-Cyclopenten-1-one, 2-hydroxy, Formic acid, ethenyl ester (Shinde et al., 2016)	1. Three new spirostanol pentaglycosides and four known saponins. The saponins were examined for inhibitory activity on tumour promoter-induced phospholipids metabolism of HeLa cells (Mimaki et al., 1996). 2. The antiproliferative effects of *n*-butanol extract from *C. comosum* was tested in vitro against four human cell lines. Results showed the extract to have antiproliferative effects and apoptosis in human cell lines (Matsushita, 2005). 3. According to a NASA study, spider plants absorb 96% of carbon monoxide in a controlled environment within a 24-hour period, making it one of the most effective air purifier in its research (Kale and Thakare, 2013). 4. Indoor ornamental plant (Adsul, 2015).
C. filipendulum	1. **1,2-benzenedicarboxylic acid, diisooctyl ester, adipic acid, diphenyl ester, Methyl-α-D-ribofuranoside, DL-Proline, 5-*oxo*-, methyl ester, hydroquinone, guanethidine (Shinde et al., 2016)	1. Indoor ornamental plant (Adsul, 2015). 2. Potential alternative for C. borivilianum due to better performance found over C. borivilianum in terms of total saponin, flavonoid, phenol content and in vitro antioxidant activity (Shinde et al., 2016).
C. glaucoides	1. Phenol, 2,4-bis(1,1-dimethylethyl), DL-proline, 5-*oxo*-, methyl ester, glycerine (Shinde et al., 2016)	1. Hawkers at Panchagani and Mahabaleshwer sales the scape as wild flowers (Adsul, 2015).
C. glaucum	1. Starch, proteins, reducing and non-reducing sugars, saponins, fats, tannin, glycoside and alkaloids (Patil et al., 2010; Patil and Deokule, 2011) 2. 1-Naphthalenecaboxaldehyde, 2-methoxy, 4-Hydroxy-2- methyl acetophenone (Shinde et al., 2016)	1. Aphrodisiac, Nourishing, Strength promoting actions, Antioxidant, General tonic and, Strength enhancer, used to cure general debility and impotency. 2. It is used as an aphrodisiac and galactagogue as well as for its nutritive, health promoting properties and immunoenhancing, hepatoprotective and antioxidants activities. The tubers are also used in fever, leucorrhoea and also as an aphrodisiac (Patil et al., 2015).
C. gothanense	1. **Dibutyl phthalate, 2-butenedioic acid (Z)-dibutyl ester, cyclopropylcarbinol, formic acid, ethenyl ester (Shinde et al., 2016)	-
C. kolhapurense	1. 1-Nonanamine, N,N-dimethyl, lactose, formic acid, ethenyl ester (Shinde et al., 2016)	1. Can be the potential source of saponins (Adsul, 2015).

Table 2 Continued.

Name of the species	Phytochemical diversity	Medicinal Properties and uses
C. laxum	1. Chlorophytoside A (Gao et al., 2005) 2. Starch, proteins, reducing and non-reducing sugars, saponins, fats, tannin, glycoside and alkaloids (Patil et. al, 2011) 3. Hexadecenoic acid, 2,3- dihydroxy propyl ester, Benzene acetic acid, 4-hydroxy-3-methoxy, 3′,5′-Dimethoxyacetophenone, Ethanone,1-(4-hydroxy-3-methoxyphenyl) (Shinde et al., 2016) 4. 25-R-Spirosta-3,5-dien-12β-ol, diosgenin, gmasterol, β-sitosterols, estigmasterol-3-O-β-D-glicopyranoside and 3-O-β-authemisol (Chu et al., 2018)	1. Tuber paste is applied on the snake bite affected area 2. Bulbs are crushed to paste and apply over the swelling of insect bite (Vijayan, 2007) 3. Used in indigenous system of medicine as galactagogue and aphrodisiac as well as for its nutritive, health promoting properties and immunoenhancing hepatoprotective and antioxidants actiivities (Patil et al., 2011). 4. Ethnobotanically the species tubers have been used for treatment of Piles and as well as an Astringent by Soliga tribes extensively even today. Roots are used to treat diarrhoea and dysentery and also used as demulcent (Kale and Thakare, 2013).
C. nepalense	1. Chlorogenic acid, kaempferol-3-*O*-(3′,6′di-O-E-*p*-coumaroyl)-β-d-glucopyranoside, and luteolin (Acharya, 2013)	1. Paste of roots mixed with mustard oil is applied in joint pains (Manandhar, 1985). 2. Farmers from Tripura, India conventionally use root extract to control dark viral necrotic lesions of sprouted potato tubers and plants (Acharya, 2013). 3. Can be a potential ornamental plant for its foliage and large flowers (Adsul 2015).
C. nimmonii	1. Tigogenin penta glycoside (Vijay et al., 2007) 2. Chloragin (**1**) (Lakshmi et al., 2009) 3. Formic acid, ethenyl ester, hydroquinone, L-proline 5-oxo-, methyl ester, phenol, 2, 4-bis (1,1-dimethylethyl), squalene (Shinde et al., 2016)	1. Antifungal activity, Antihyperglycemic, Antihyperlipidemic activity (Lakshmi et al., 2009). 2. Can be a potential ornamental plant for its foliage and large flowers (Adsul, 2015).
C. tuberosum	1. Starch, protein, tannin, saponin, steroids, sugars, fats, alkaloids, glycosides (Patil and Deokule, 2011) 2. Phenol, 4-(3-hydroxy-1-propenyl)-2-methoxy **Tetradonium bromide, Methyl-α-d-ribofuranoside, benzene, 1-chloro-4-methoxy, Hydroquinone, 2-furancarboxaldehyde, 5-(hydroxymethyl) (Shinde et al., 2016). 3. 12-Methyl-E-E-2.13 octadecadien-1-ol, hexadecanoic acid, 1-(hydroxymethyl)-1,2-ethanediyl ester (Kagale, 2016)	1. Roots are used to treat diarrhoea and dysentery and also used as demulcent and galactagogue (Dabur, 2007). 2. The tuberous root is washed and then dried. 1gm. powder of tuberous root is mixed with water and given to male as tonic. 3. The root powder is given to animal to cure fractured bone. 4. Small amount of tuber is given to female to check Leucorrhoea (Swarnkar and Katewa, 2008). 5. In West Bengal, it is used abundantly as ‘safed musli’ by the village based traditional medical practitioners in this state of India (Mandal and Nandi, 2013).

*All the chemical properties including extractions are totally related to root part of the specimens.
** Underlined compounds are Phthalates or quaternary ammonium and are kown to be contaminants and not natural products (Bianco et al., 2014; Venditti, 2020).

by Bodele (2016) for alkaloid, flavonoids, tannins, saponin, glycosides, steroids and sterol. Quantification of stigmasterol was also done by HPTLC with the help of standard material of stigmasterol. The maximum amount of stigmasterol was observed in *C. bharuchae*. Adulteration of 5 market samples of Safed musli differentiated with all species of *Chlorophytum*. Shinde et al. (2016) carried out a comparative study of twelve species together with *C. borivilianum* to find its substitute for phytochemical content and antioxidant potential. HPTLC fingerprint of *C. amaniense* showed the presence of the maximum number of bands. GC-MS analysis of all the extracts revealed the presence of 35 different molecules. The study revealed an efficient and relative assessment of the genus, specifies *C. amaniense* as an alternate to *C. borivilianum*.

In the last several decades, endangered medicinal plants are often used as an alternative resource. Due to severe deforestation extinction of many medicinal plant species were occurred. It leads to scarcity of the plants which ultimately resulted in adulteration. In India out of the 8000 harvested medicinal plants around 960 are ineffective trade. For promoting herbal medicinal products adulteration is the ultimate pitfall. For the better future of herbal medicine authentic identification, standardization and quality assurance are most essential. Corresponding to this the comparative anatomical and phytochemical assessment is necessary which leads to exact identification and prevention of adulteration. In this context, Parveen and Singh (2018) studied different *Chlorophytum* and *Asparagus* species with standard reference of preliminary phytochemical analysis and comparative anatomical study. Which ultimately uncovered precise identification and can be retained to prevent delusion and adulteration.

With the aim of botanical authentication Thakre and Sharma (2019) carried out Pharmacognostic study in *Chlorophytum kolhapurens* and *C. bharuchae*. In this investigation micromorphological, physicochemical, phytochemical and WHO endorsed factors have been accomplished. These factors will be useful in standerdization and valuable in authentication of *Chlorophytum* species.

Similarly, Nalawade (2018); Nalawade and Gurav (2020) studied the High Resolution Liquid Chromatography coupled with Mass Spectroscopy (HR-LCMS) analysis conducted in root powder methanolic extract of 18 species of *Chlorophytum* and *Asparagus racemosus* Willd. (outgroup) revealed the presence of total 365 phytoconstituents which are known to exhibit medicinal as well as physiological activities. Therefore, extracts from these plants could be seen as a good source of useful drugs. 28 phytochemical constituents have been found to be present in 50% species. While ecgonine and 2-docosanamidoethanesulfonic acid are the constituents present in all nineteen species. The dendrogram is produced on the basis of chemical characters by clustering the analysis of HR-LCMS data. The distribution of the phytochemicals in the clusters represents the separation of species and high diversity in phytoconstituents.

Quantification of saponin content from 17 species of *Chlorophytum* by the high performance liquid chromatography (HPLC) was performed by Nalawade (2018); Nalawade and Gurav (2020). Analysis of saponin content by HPLC showed that the highest content of saponin was found in *C. bharuchae* (2.59 ± 0.19 mg/100mg) collected from Appachiwadi followed by *C. gothanense* (2.09 ± 0.08 mg/100mg) collected from Gothane. The lowest saponin content was observed in *C. laxum* (0.56 mg/100mg) collected from Siddharabetta. Investigated data may suggest phytochemical diversity in different species is possibly because of genetic variances and geographical conditions. Hence, it can be advised that *C. bharuchae* is the finest performer and being the chief accumulator of saponin and a potential source of cultivation and breeding prospects with proper validation.

Usually, Ayurveda medicine uses natural vegetation for the preparations. Due to heightened needs, there is a scarcity of raw materials which ultimately led to high cost and adulteration of the drugs. In addition to that local distributional inequality and unscientific collection outcomes into the inferior quality of raw material drastically impacts the therapeutic efficacy. Thus, quality standardization in different drug formulations is most significant. 'Musali' is a multipurpose drug especially used in yogas and gynecological treatments. Among the two varieties 'Sweta musali' (*Chlorophytum borivilianum* and *Asparagus adscendens*) and Krishna musali (*Curculigo orchioides*) reported in 'Raja Nigantu' Krishna musali is most preferable due to its exceptional pharmacological properties. Remya et al. (2019) phramcognostically analyzed the market samples of both the musalis from Kerala. Macroscopic features of the market sample resemble *Curculigo orchioides* which ultimately validates the traditional claim of Raja Nighantu. This study showed that the Kerala market prefers musali as *Curculigo orchioides* only. Generally, Shatavari (*Asparagus racemosus*) is medicinally used in children, lactating mothers and elderly patients. Instead of *Asparagus* if *Chlorophytum* species will be used for the treatment in these people it can cause severe side effects. Market preparations often intermixed with both these plants. Jay et al. (2021) studied market samples of both these plant species with TLC, NMR and GCMS study and isolated a marker by spectral analysis which is to be 2, 4, 6, 10, 18, 22- tetracosahexaene. Only *Chlorophytum* species showed the presence of this marker. Industrially this work will be very much useful for the detection of adulteration. Such trials can substantiate the veracity of the conventional medicine system of India.

8. Concluding remarks

Still, the genus is mistreated only on the basis of the traditional system which is based on morphological characteristics and traditional attributes. The newly described species are lacking the approaches of molecular and phytochemical analysis. Concerning the review, the commercial exploitation will drive *Chlorophytum* to RET status which emphasizes the need

for conservation of the species. The morphological, micromorphological, anatomical, molecular and phytochemical analysis will be helpful in resolving taxonomic uncertainties. In the recent past, these species have got reasonable medicinal importance. Furthermore, people are believing more on herbal medicines. Because of this, it has got good export value in the international market of phytomedicine with aphrodisiac characteristics. The results from population survey, morphological diversity, molecular analysis and field studies can be further used for proper selection by which the species or cultivar is made and the proper cultivation practices are developed, the 'Safed Musali' can become an important cash crop or ornamentaly important varity with minimum care. The phytochemical diversity obtained is proving to be an increasingly valuable reservoir of bioactive compounds of significant medicinal value and can be utilized in confound morphological identification, conservation strategies and sustainable development. Advanced molecular tools and comparative phytochemical anatomical screening practices against adulteration-related issues can play a vital role in bioprospecting studies of genus *Chlorophytum* as with other plants available in India.

Abbreviations: AFLP: Amplified Fragment Length Polymorphism; DNA: Deoxyribonucleic acid; HPLC: High Performance Liquid Chromatography; HPTLC: High Performance Thin Layer Chromatography; ITS: Internal Transcribed Spacer; RAPD: Random amplified polymorphic DNA; RET: Rare Endangered Threatened; RFLP: Restriction Fragment Length Polymorphism; SEM: Scanning Electron Microscopy; SSR: Simple Sequence Repeat; TLC: Thin Layer Chromatography.

Conflict of interest

The authors declare that there is no conflict of interest.

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